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Ecohydraulics and River Ecosystem Interactions: Processes, Modelling and Restoration Perspectives

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ABSTRACT

Ecohydraulics is an interdisciplinary field which studies the mutual interactions between hydraulic processes and riverine ecosystems. Rivers are dynamic systems where flow regime, sediment transport, channel morphology and vegetation together controls habitat availability and ecological functions. In many regions, anthropogenic modifications such as dams, channelization and pollution have disturbed the natural ecohydraulic balance, causing biodiversity decline and habitat degradation. This review paper discusses fundamental principles of ecohydraulics, major river ecosystem components, hydraulic–ecological feedback mechanisms and modelling approaches used for understanding riverine habitats. The paper also highlights restoration strategies based on ecohydraulic concepts such as environmental flows, nature-based river engineering and habitat enhancement. A synthesis of recent advances in field monitoring, numerical simulation and ecological assessment methods is provided. Challenges such as scale mismatch, climate change impacts and uncertainty in ecohydraulic prediction are also discussed. The review shows that integrated ecohydraulic frameworks are essential for sustainable river management and ecological conservation.

KEYWORDS: *Ecohydraulics, River ecosystems, Environmental flows, Habitat modelling, Sediment transport, River restoration*

INTRODUCTION

Rivers are not only hydraulic conduits conveying water and sediments but also complex ecological corridors supporting diverse aquatic and riparian life. Traditional hydraulic engineering mainly focused on flood control, navigation and water supply, often ignoring ecological consequences. This has resulted in channel simplification, loss of habitats and altered flow regimes. Ecohydraulics emerged to bridge the gap between hydraulic sciences and ecology, aiming to understand how physical river processes influence biological communities and vice versa.

Ecohydraulics integrates fluid mechanics, geomorphology and ecology to study how flow patterns, turbulence, sediment movement and channel form affect organisms such as fish, benthic macroinvertebrates and riparian vegetation. Conversely, organisms also modify hydraulics through bio-stabilization of sediments, roughness alteration and channel morphology changes. Therefore, river systems function as coupled hydro-eco-morphological systems.

In the context of climate variability and increasing water demand, sustainable river management requires understanding these interactions. Ecohydraulic studies help determine environmental flow requirements, design fish passages, restore habitats and maintain ecological connectivity. This paper reviews the major concepts and interactions governing ecohydraulics and river ecosystems, with focus on processes, modelling and restoration applications.

FUNDAMENTALS OF ECOHYDRAULICS

Ecohydraulics deals with the interactions between hydraulic processes and ecological responses in flowing water systems. Rivers are not purely physical systems governed only by fluid mechanics; they are living environments where hydraulic forces continuously interact with organisms, sediments and vegetation. The movement of water determines transport of nutrients, sediments and organisms, while biological components modify channel resistance, morphology and stability. Therefore ecohydraulics can be seen as the study of coupled hydro-bio-geomorphic processes.

Hydraulic variables such as velocity distribution, depth variation, turbulence structure and shear stress influence organism behaviour, feeding, respiration and habitat selection. At the same time, organisms such as plants, algae, fish and benthic fauna alter the hydraulic field through roughness, drag forces and sediment trapping. This two-way interaction forms the basis of ecohydraulic science.

Understanding these processes is important because ecological health of rivers depends on maintaining suitable hydraulic habitats. Alterations in flow regime due to dams, diversion or climate change disturb these hydraulic–ecological relationships and lead to habitat degradation. Hence ecohydraulics provides a framework to quantify how physical river conditions support ecological integrity.

Hydraulic Parameters Relevant to Ecology

Hydraulic parameters define the physical environment experienced by aquatic organisms. Even small changes in these parameters can influence survival, growth and reproduction of species. The main hydraulic variables with ecological relevance are described below.

Flow Velocity and Spatial Distribution

Flow velocity is one of the most critical factors controlling habitat suitability. It affects swimming ability of fish, feeding efficiency, oxygen transfer and sediment transport.

Different organisms have evolved to live within specific velocity ranges:

- Fish species select velocities that balance energy expenditure and food availability
- Juvenile fish prefer low-velocity refuge zones near banks or behind obstacles
- Invertebrates often colonize moderate-velocity riffles where oxygen is high
- Excessively high velocities may displace organisms downstream

Velocity distribution within a channel is rarely uniform. Variations occur due to channel shape, roughness elements, vegetation patches and bedforms. These variations create microhabitats such as recirculation zones, shear layers and wake regions that provide shelter and feeding sites.

Water Depth and Stage Fluctuations

Water depth controls hydraulic pressure, habitat volume and connectivity between channel and floodplain.

It determines:

- Available swimming space for fish
- Light penetration affecting plant growth
- Thermal stratification
- Predator–prey interactions

Depth fluctuations caused by seasonal flows or hydropeaking operations can strongly influence ecological cycles. For example, sudden water level drops may strand fish or expose eggs laid on shallow gravels. Seasonal inundation of floodplains supports spawning, nutrient exchange and vegetation regeneration.

Turbulence Intensity and Eddies

Turbulence refers to chaotic velocity fluctuations in flowing water. Although often considered a hydraulic property, turbulence has major ecological implications:

- Enhances oxygen mixing and nutrient transport
- Influences swimming behaviour of fish
- Creates eddies used as energetic refuge
- Affects drift of plankton and larvae

Fish often exploit turbulent structures to reduce swimming effort by positioning in low-velocity eddies. However excessive turbulence can increase stress or disorientation. Turbulence characteristics such as eddy size and frequency therefore influence habitat selection.

Shear Stress on River Bed

Bed shear stress represents the force exerted by flowing water on the substrate. It controls sediment mobility and stability of benthic habitats. Ecological significance includes:

- Determines whether gravel beds remain stable for spawning
- Influences attachment of algae and invertebrates
- Controls erosion of biofilms
- Affects interstitial flow and oxygen exchange in sediments

Low shear environments favour deposition of fine sediments, which may suffocate benthic organisms. High shear zones maintain coarse substrate but may be too unstable for colonization. Therefore intermediate shear conditions often provide optimal habitats.

Substrate Stability and Composition

Although not purely hydraulic, substrate conditions are closely linked with flow and shear stress.

Substrate stability affects:

- Spawning success of fish
- Burrowing organisms
- Benthic community structure
- Root anchorage of aquatic plants

Stable gravels provide interstitial spaces for eggs and larvae, while unstable sands shift during floods. Hydraulic sorting processes determine substrate distribution across riffles, pools and bars, creating habitat heterogeneity.

Hydraulic Heterogeneity and Habitat Diversity

The combination of velocity, depth, turbulence and substrate variability forms a mosaic of microhabitats. Such spatial heterogeneity is essential for biodiversity because different species occupy different hydraulic niches. Natural rivers typically show high heterogeneity due to complex morphology, while engineered channels often lack it, resulting in ecological simplification.

Ecological Components of River Systems

River ecosystems consist of multiple biological components interacting with hydraulic and geomorphic processes. These components occupy different zones of the river corridor and respond to hydraulic conditions in distinct ways.

Aquatic Fauna (Fish and Invertebrates)

Fish and benthic macroinvertebrates are primary biological indicators of ecohydraulic conditions. Their distribution depends strongly on:

- Flow velocity preference
- Depth requirements
- Substrate type
- Shelter availability

- Temperature and oxygen

Fish use different hydraulic habitats during life stages such as spawning, feeding and refuge. Invertebrates colonize substrates depending on flow and sediment stability. Riffles usually support diverse insect larvae due to high oxygen, while pools support slow-water species.

Aquatic Vegetation and Algae

Submerged plants, emergent macrophytes and algae interact directly with hydraulic forces. Flow affects plant growth, morphology and spatial distribution:

- Moderate flow enhances nutrient supply
- Strong flow may uproot vegetation
- Low flow promotes excessive algal growth

Vegetation patches alter local hydraulics by increasing drag and reducing velocity, creating depositional zones. These zones trap fine sediments and organic matter, forming productive habitats.

Riparian Vegetation

Riparian plants grow along river banks and floodplains where soil moisture and periodic flooding occur. Their ecological and hydraulic roles include:

- Stabilizing banks through root reinforcement
- Providing shade and organic input
- Regulating channel width
- Creating hydraulic roughness

Riparian zones also serve as transition areas between aquatic and terrestrial ecosystems, supporting biodiversity and nutrient cycling.

Microbial Communities

Microorganisms such as bacteria and fungi form biofilms on submerged surfaces. They play important roles in nutrient transformation, organic matter decomposition and sediment cohesion.

Flow conditions influence microbial colonization by controlling nutrient delivery and shear stress. Stable substrates in moderate flow zones often host rich microbial biofilms.

Floodplain Ecosystems

Floodplains are periodically inundated areas adjacent to rivers. They function as ecological hotspots with high productivity. Hydraulic connectivity between channel and floodplain allows:

- Nutrient exchange
- Fish spawning and nursery habitats
- Sediment deposition
- Vegetation regeneration

Regulation of rivers often reduces floodplain inundation, leading to ecological degradation. Therefore floodplain ecosystems are essential component of river ecohydraulics.

Ecohydraulic Feedback Mechanisms

A defining feature of ecohydraulics is the feedback between organisms and hydraulic processes. Rather than being passive recipients of flow conditions, biological components actively modify hydraulics and morphology.

Vegetation Effects on Flow Resistance

Aquatic and riparian vegetation increases hydraulic roughness. Stems and leaves obstruct flow, causing:

- Reduced velocity within vegetation patches
- Increased turbulence at patch edges
- Flow diversion around plants
- Energy dissipation

These effects create low-velocity refuge zones used by fish and invertebrates. At larger scales, vegetation can influence channel pattern and flood conveyance.

Root Stabilization and Sediment Dynamics

Plant roots reinforce soil and sediments, increasing resistance to erosion.

This stabilization:

- Limits bank erosion
- Promotes sediment deposition
- Maintains channel geometry
- Supports bar formation

Vegetation-induced sediment trapping can gradually build floodplain surfaces and alter channel morphology.

Biotic Sediment Trapping and Organic Accumulation

Organisms such as macrophytes, algae and microbial mats trap suspended sediments and organic particles. This process changes bed composition and nutrient availability. Organic matter accumulation supports detrital food webs and influences oxygen demand in sediments.

Channel Form and Habitat Modification

Changes in channel morphology alter hydraulic patterns, which then affect ecological conditions. For example:

- Bar formation creates shallow habitats
- Meanders generate pools and riffles
- Vegetated islands divide flow
- Large woody debris forms scour pools

These morphological structures provide habitat complexity. Biological and hydraulic processes therefore co-evolve through feedback loops.

Self-Organizing River Ecosystems

Over long timescales, interactions between flow, sediment and biota lead to self-organized river landscapes. Vegetation colonizes stable bars, modifies flow, traps sediments and eventually forms floodplain surfaces. Similarly, organisms respond to hydraulic niches while also shaping them. Such co-evolution explains the diversity and resilience of natural rivers.

RIVER HYDRAULICS AND HABITAT FORMATION

River hydraulics plays a fundamental role in shaping channel morphology and determining the spatial distribution of habitats. The movement of water and sediment continuously modifies bedforms, channel geometry and floodplain connectivity, leading to formation of diverse ecological niches. Natural rivers are characterized by variability in flow magnitude and sediment supply across seasons and years, which creates dynamic habitats suitable for different species and life stages.

Hydraulic processes such as flow acceleration, deceleration, turbulence generation and sediment entrainment form distinct geomorphic units including pools, riffles, bars, backwaters and side channels. These units differ in depth, velocity, substrate composition and hydraulic stability. Such heterogeneity is essential for sustaining biodiversity because organisms require different hydraulic environments for feeding, refuge and reproduction.

Human interventions like dams, channel straightening and bank protection often simplify hydraulic patterns and reduce morphological diversity. This results in loss of microhabitats and ecological degradation. Therefore understanding the link between hydraulics and habitat formation is central to ecohydraulic science and river restoration.

Flow Regime and Ecological Function

The natural flow regime describes temporal variation in river discharge and water level. It is commonly characterized by five components: magnitude, frequency, duration, timing and rate of change. These components together regulate ecological processes and life cycles in river ecosystems.

Magnitude of Flow

Flow magnitude refers to discharge volume and water depth during different hydrological conditions such as low flow, normal flow and floods. Ecological significance includes:

- Determines available wetted habitat area
- Controls channel connectivity and depth
- Influences velocity fields and hydraulic energy
- Affects dilution of pollutants and nutrient concentration

Low flows may restrict habitat space and increase temperature stress, while moderate flows maintain suitable living conditions. High flows reshape channels and create new habitats.

Frequency of Flow Events

Frequency describes how often specific flow events occur, such as seasonal floods or droughts.

Many organisms adapt to predictable recurrence patterns:

- Periodic floods trigger fish migration and spawning
- Regular inundation maintains floodplain wetlands
- Repeated flushing prevents excessive sediment accumulation

Changes in flood frequency due to regulation disturb ecological rhythms and may reduce reproductive success of aquatic species.

Duration of Flow Conditions

Duration refers to how long certain flow levels persist. Ecological effects include:

- Length of floodplain inundation influencing plant germination
- Persistence of low flows affecting aquatic survival
- Time available for nutrient exchange between channel and floodplain

Shortened flood duration can reduce wetland productivity, while prolonged drought can cause habitat contraction and mortality.

Timing (Seasonality)

Timing indicates when flows occur within a year. Seasonal flow patterns are closely linked with biological cycles:

- Spring floods coincide with fish spawning in many rivers
- Monsoon flows support sediment renewal and channel maintenance
- Seasonal inundation regulates riparian vegetation growth

When dams shift seasonal peaks (e.g., storing monsoon water and releasing in dry season), ecological synchrony between flow and life cycles is disturbed.

Rate of Change (Hydropeaking Effects)

Rate of change refers to how quickly discharge increases or decreases. Rapid fluctuations caused by hydropower operations can have severe ecological consequences:

- Sudden water level rise may displace organisms

- Rapid drawdown may strand fish or invertebrates
- Instability reduces habitat predictability

Natural rivers usually show gradual hydrographs, allowing organisms to adapt. Artificial fluctuations create stress conditions.

Ecological Outcomes of Natural Flow Regime

Together these flow characteristics support key ecological functions:

- Fish migration and spawning cues
- Floodplain nutrient exchange
- Sediment transport and channel renewal
- Habitat connectivity across river corridor

When flow regime is altered by dams or abstraction, ecological functions decline, leading to reduced biodiversity and simplified habitats.

Sediment Transport and Substrate Composition

Sediment transport is another major hydraulic process shaping river habitats. Rivers transport particles ranging from clay to boulders depending on flow energy. The balance between sediment supply and transport capacity determines bed composition and stability, which directly affects ecological suitability.

Grain Size Distribution

Sediment size strongly influences habitat quality:

- Coarse gravels provide interstitial spaces for fish eggs
- Cobbles support attached invertebrates and algae
- Sands offer habitat for burrowing organisms
- Fine silts often reduce permeability and oxygen exchange

Hydraulic sorting during floods distributes grain sizes spatially, forming riffles with coarse material and pools with finer sediments.

Bed Mobility and Stability

Bed mobility refers to how easily sediments move under flow. Ecological implications include:

- Stable beds allow colonization by plants and benthic fauna
- Excessively mobile beds disturb habitats
- Periodic movement maintains substrate renewal

Fish spawning often requires moderately stable gravels that are not displaced during normal flows but cleaned during floods.

Sediment Sorting Processes

Flow turbulence and velocity gradients sort sediments by size and density. Sorting produces layered or patchy substrates with ecological significance:

- Coarse patches create refuge for macroinvertebrates
- Fine patches support burrowing organisms
- Mixed sediments enhance biodiversity

Natural sorting increases habitat heterogeneity, while regulated rivers often show uniform substrates.

Formation of Bars and Riffles

Sediment transport leads to creation of morphological units such as bars and riffles:

- Riffles form where coarse sediments accumulate in shallow fast-flow areas
- Bars form where flow decelerates and deposits material
- Pools develop in scour zones

These units provide contrasting hydraulic conditions essential for aquatic communities.

Ecological Impacts of Fine Sediment Deposition

Excess fine sediment from erosion or human activities can degrade habitats:

- Clogging of gravel interstices reduces oxygen supply
- Smothering of benthic organisms
- Reduced spawning success
- Increased turbidity affecting feeding

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Therefore maintaining natural sediment regime is important for habitat quality.

Channel Morphology and Habitat Diversity

Channel morphology refers to the three-dimensional shape and planform of the river channel. It develops through interaction of flow and sediment processes and directly determines habitat diversity.

Natural rivers exhibit complex morphology including pools, riffles, meanders, bars, islands and side channels.

Pool–Riffle Sequences

Alternating pools and riffles are characteristic of many gravel-bed rivers:

- Pools: deep, slow-flow zones providing refuge and overwintering habitat for fish
- Riffles: shallow, fast-flow zones with high oxygen supporting invertebrates

This sequence creates longitudinal habitat diversity along the river.

Meanders and Point Bars

In meandering rivers, curvature generates hydraulic asymmetry:

- Outer bends experience erosion and deep pools
- Inner bends deposit sediments forming point bars
- Helical flow creates varied velocity fields

These features support vegetation colonization and diverse aquatic habitats.

Mid-Channel Bars and Islands

Bars and islands divide flow and create secondary channels:

- Provide shallow low-velocity zones
- Support riparian vegetation establishment
- Create refuge during floods
- Increase channel complexity

Vegetated islands can stabilize and reshape channel planform.

Side Channels and Backwaters

Side channels form when flow splits around bars or floodplain features.

Ecological importance includes:

- Nursery habitats for juvenile fish
- Low-energy refuge during floods
- High productivity zones
- Biodiversity hotspots

Backwaters often accumulate organic matter and support unique communities.

Floodplain Connectivity

Morphology controls connectivity between main channel and floodplain. During floods:

- Water spreads across floodplain
- Nutrients and sediments are exchanged
- Wetland habitats are created
- Fish access spawning grounds

Disconnected floodplains due to levees or channelization reduce ecological diversity.

Habitat Heterogeneity and Biodiversity

Complex channel morphology creates variation in:

- Depth
- Velocity
- Substrate
- Flow direction
- Stability

Such heterogeneity supports multiple species and life stages. Uniform channels, in contrast, provide limited ecological niches and lower biodiversity.

Table 1: Morphological Features and Associated Habitats

Feature	Hydraulic Condition	Ecological Role
Pools	Deep, low velocity	Refuge for fish
Riffles	Shallow, high velocity	Oxygenation, invertebrates
Point bars	Moderate flow	Vegetation colonization
Side channels	Variable	Nursery habitats
Floodplain	Seasonal flow	Nutrient cycling

These morphological units are essential for sustaining biodiversity.

INFLUENCE OF BIOTA ON RIVER HYDRAULICS

Organisms themselves modify hydraulic conditions, forming ecohydraulic feedbacks.

Riparian Vegetation Effects

Riparian plants affect river hydraulics by:

- Increasing bank roughness
- Reducing flow velocity
- Stabilizing banks
- Promoting sediment deposition

Vegetation also shapes channel planform and meandering behavior.

Aquatic Vegetation and Flow Resistance

Submerged and emergent plants modify flow structure:

- Create wake zones and turbulence
- Reduce near-bed velocity
- Trap sediments
- Provide shelter for fauna

Dense vegetation can alter flow distribution across channel.

Biogenic Sediment Stabilization

Organisms such as algae, microbes and roots bind sediments.

This process:

- Reduces erosion
- Enhances bed stability
- Changes sediment transport thresholds

Such biological stabilization is important in low-energy rivers.

ECOHYDRAULIC MODELLING APPROACHES

Modelling helps predict habitat conditions and ecohydraulic responses to river modifications.

Hydraulic Habitat Models

Habitat models combine hydraulic variables with species preferences to estimate habitat suitability.

Common approaches:

- Habitat suitability curves
- Weighted usable area (WUA)
- Instream flow incremental methodology

These models estimate ecological impacts of flow changes.

Ecohydraulic Numerical Simulation

Two-dimensional and three-dimensional models simulate flow fields and habitats.

Applications include:

- Fish habitat prediction
- Sediment–vegetation interactions
- Floodplain connectivity analysis
- Restoration design evaluation

Coupled hydro-morphodynamic models simulate long-term ecohydraulic evolution.

Individual-Based and Agent Models

These models simulate behavior of organisms under hydraulic conditions:

- Fish movement in flow fields

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- Habitat selection
- Energy expenditure
- Population dynamics

Such models improve ecological realism compared to static habitat indices.

ENVIRONMENTAL FLOWS AND RIVER ECOSYSTEMS

Environmental flows aim to maintain ecological processes in regulated rivers.

Concept of Environmental Flow

Environmental flow refers to water regime needed to sustain ecosystems and human benefits.

It considers:

- Seasonal variability
- Flood pulses
- Low-flow thresholds
- Ecological requirements

Ecohydraulics helps define flow–habitat relationships.

Flow Alteration Impacts

Hydraulic alterations affect ecosystems by:

- Reducing habitat diversity
- Interrupting migration
- Changing sediment regime
- Disconnecting floodplains

Dams often reduce peak flows and increase base flows, altering natural dynamics.

Ecohydraulic Flow Assessment

Ecohydraulic tools evaluate environmental flow requirements using:

- Hydraulic habitat simulation
- Flow duration curves
- Species preference modelling

- Morphological assessment

These approaches guide river regulation policies.

RIVER RESTORATION USING ECOHYDRAULIC PRINCIPLES

Ecohydraulics provides scientific basis for restoring degraded rivers.

Channel Re-naturalization

Restoration aims to recreate natural morphology:

- Meanders and riffle–pool sequences
- Floodplain reconnection
- Side channel creation
- Gravel augmentation

These measures enhance hydraulic heterogeneity and habitats.

Vegetation-Based Restoration

Planting riparian and aquatic vegetation:

- Stabilizes banks
- Improves habitat complexity
- Enhances sediment retention
- Provides shading and nutrients

Vegetation acts as natural hydraulic engineer.

Nature-Based Hydraulic Structures

Eco-friendly structures include:

- Engineered log jams
- Rock weirs
- Root wads
- Deflectors

They modify flow locally and create habitat diversity.

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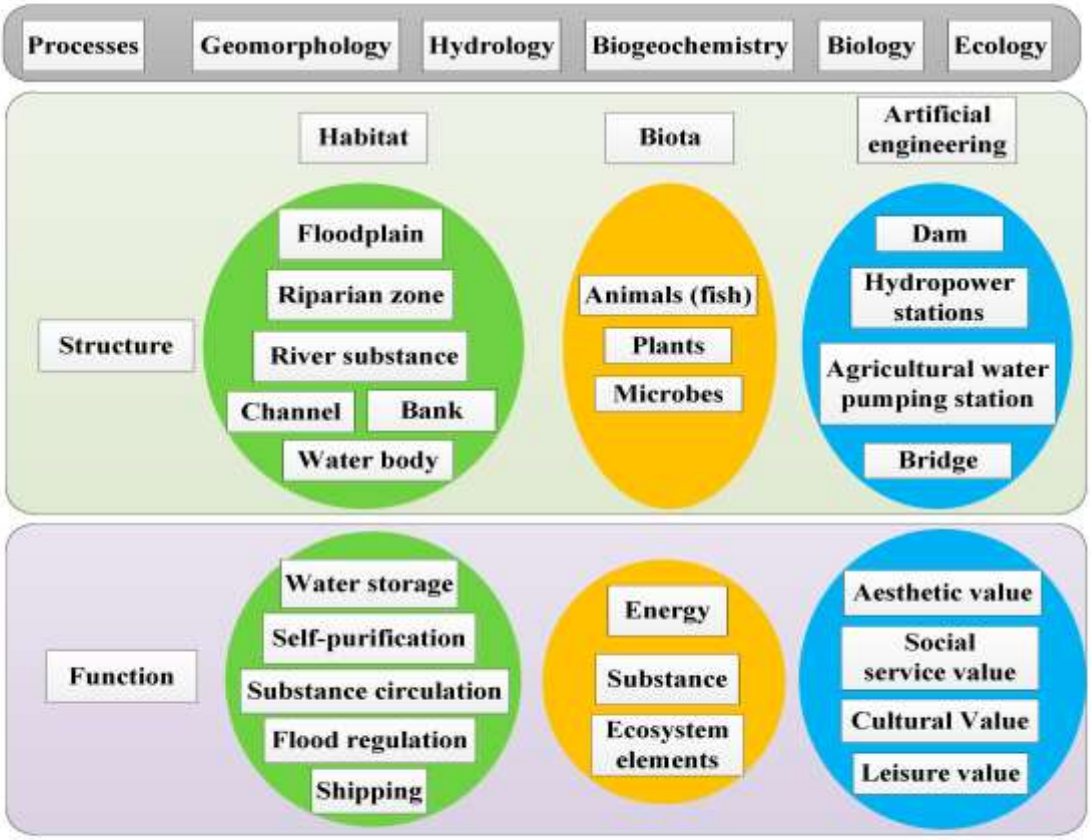

Figure 1: Conceptual Ecohydraulic Interactions in River Restoration

CLIMATE CHANGE AND ECOHYDRAULIC DYNAMICS

Climate change modifies river hydrology and ecohydraulics.

Hydrological Variability

Projected impacts include:

- Increased floods and droughts
- Altered seasonal flows
- Glacier melt changes
- Extreme events

Such variability affects habitat stability and species survival.

Morphological Adjustments

Changing flows alter:

- Sediment transport rates
- Channel erosion

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- Floodplain processes
- Vegetation patterns

These shifts reshape ecohydraulic equilibrium.

Ecosystem Responses

Ecological impacts include:

- Species migration shifts
- Habitat fragmentation
- Invasive species spread
- Biodiversity loss

Ecohydraulic models are needed to predict future scenarios.

MONITORING AND MEASUREMENT TECHNIQUES

Advances in monitoring improved ecohydraulic understanding.

Hydraulic Measurements

Modern techniques include:

- Acoustic Doppler velocimetry
- Particle image velocimetry
- Remote sensing bathymetry
- UAV mapping

These provide detailed flow and morphology data.

Ecological Surveys

Ecological assessment methods:

- Fish sampling
- Benthic macroinvertebrate surveys
- Vegetation mapping
- Habitat classification

Combined with hydraulics, they reveal ecohydraulic relations.

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Integrated Monitoring Framework

Ecohydraulic monitoring integrates:

- Hydrology
- Hydraulics
- Sediment
- Biology
- Water quality

Such datasets support modelling and restoration evaluation.

CHALLENGES IN ECOHYDRAULIC RESEARCH

Despite progress, ecohydraulics faces several challenges.

Scale Mismatch

Hydraulic processes operate at small scales while ecological processes often at larger scales. Linking those remains difficult.

Data Limitations

Ecohydraulic studies require long-term and multi-disciplinary data, which is often limited.

Model Uncertainty

Habitat and ecological models involve uncertainty due to species behavior complexity and environmental variability.

Human Pressures

Urbanization, pollution and water abstraction continue altering river ecohydraulics.

FUTURE DIRECTIONS

Future ecohydraulic research should focus on:

- Coupled hydro-eco-morphodynamic modelling
- Climate-resilient river management
- Nature-based engineering solutions
- Ecohydraulic indicators for policy
- Integration with socio-ecological systems

Interdisciplinary collaboration is essential.

CONCLUSION

Ecohydraulics provides a holistic framework for understanding interactions between river hydraulics and ecosystems. Flow regime, sediment transport and channel morphology jointly shape habitats and biodiversity. Biological components such as vegetation and organisms also influence hydraulic processes through feedback mechanisms. Ecohydraulic modelling and environmental flow assessment are important tools for sustainable river management. Restoration strategies based on ecohydraulic principles can improve habitat diversity and ecological connectivity. However, challenges such as scale mismatch, climate change and data uncertainty remain. Future research integrating hydraulics, ecology and geomorphology will be critical for conserving river ecosystems under increasing environmental pressures. Sustainable river engineering must adopt ecohydraulic concepts to balance human needs with ecological integrity.

REFERENCES

1. J. D. Allan and M. M. Castillo, *Stream Ecology: Structure and Function of Running Waters*, Springer, 2007.
2. P. S. Kemp and J. D. Williams, "Ecohydraulics: an integrated approach to river science," *Hydrobiologia*, 2010.
3. M. A. Palmer et al., "Standards for ecologically successful river restoration," *Journal of Applied Ecology*, 2005.
4. S. J. Ormerod, "River restoration and biodiversity," *Aquatic Conservation*, 2014.
5. D. M. Hannah et al., "Hydrology and ecohydrology: a global perspective," *Hydrological Processes*, 2004.
6. P. B. Bayley, "The flood pulse concept in river ecosystems," *Canadian Journal of Fisheries*, 1995.
7. H. Piégay and N. Schumm, *River Restoration and Management*, Wiley, 2003.
8. S. Nikora, "Hydrodynamics of aquatic ecosystems," *Journal of Hydraulic Research*, 2010.
9. A. Gurnell, "Plants as river system engineers," *Earth Surface Processes*, 2014.
10. K. Tockner and J. A. Stanford, "Riverine floodplains: present state and future trends," *Environmental Conservation*, 2002.

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